LA-UR - 80-3366

CONF-801217--1

TITLE: AN OVERVIEW OF RESUSPENSION MODELS: APPLICATION TO LOW LEVEL WASTE MANAGEMENT

MASTER

AUTHOR(S): J. W. Healy

SUBMITTED TO: Symposium on Modeling and Low-Level Waste Management: An Interagency Workshop, Denver, CO, December 1-4, 1980

DISCLAIMER

University of California



DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

LOS ALAMOS SCIENTIFIC LABORATORY
Post Office Box 1663 Los Alamos, New Mexico 87545
An Affirmative Action/Equal Opportunity Employer

# AN OVERVIEW OF RESUSPENSION MODELS: APPLICATION TO LOW LEVEL WASTE MANAGEMENT

J. W. Healy

Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87545

## ABSTRACT

Resuspension is one of the potential pathways to man for radioactive or chemical contaminants that are in the biosphere. In waste management, spills or other surface contamination can serve as a source for resuspension during the operational phase. After the low-level waste disposal area is closed, radioactive materials can be brought to the surface by animals or insects or, in the long term, the surface can be removed by erosion. Any of these methods expose the material to resuspension in the atmosphere. Intrusion into the waste mass can produce resuspension of potential hazard to the intruder. Removal of items from the waste mass by scavengers or archeologists can result in potential resuspension exposure to others handling or working with the object. The ways in which resuspension can occur are wind resuspension, mechanical resuspension and local resuspension. While methods of predicting exposure are not accurate, they include the use of the resuspension factor, the resuspension rate and mass loading of the air.

## INTRODUCTION

Resuspension and inhalation of the resuspended material is a potential pathway whereby radioactive materials can be transferred from the ground, or other surface, to man. In general, it is of greatest importance for those radionuclides that are strongly discriminated against in the food pathway. If the radionuclides are strongly taken up by foods, and food from the contaminated area is used, the contribution to the dose from resuspension and inhalation is usually small.

In this paper, we discuss the application of this pathway to the management of low level wastes and describe briefly some of the methods of estimating air concentrations from resuspended material. More detailed discussions of the technical details are available in the literature [1,2].

## RESUSPENSION

Before entertaining the question of how resuspension is involved in low-level waste management, let us consider what resuspension is. Technically, it is the suspension of a material in a fluid after this material has once been deposited on a surface from a previous suspension. Thus, resuspension. This fluid can be either air or water and resuspension in both can be of importance in analyzing potential problems from low-level wastes. Air suspension is used in estimating quantities inhaled and water suspension is important in the movement of radioactive particles in streams or other bodies of water. However, for this discussion, we will confine our attention to the problem of suspension in air.

It should be apparent that not all sources meet the technical definition of resuspension given above. For example, if a radioactive material is spilled on the surface or if it moves upward to the surface, it has not been deposited by a previous suspension and should not really be considered as resuspension. However, because the mechanisms for suspension are similar regardless of the method of contamination, it is convenient to change the definition to include all cases in which the material becomes airborne from the surface.

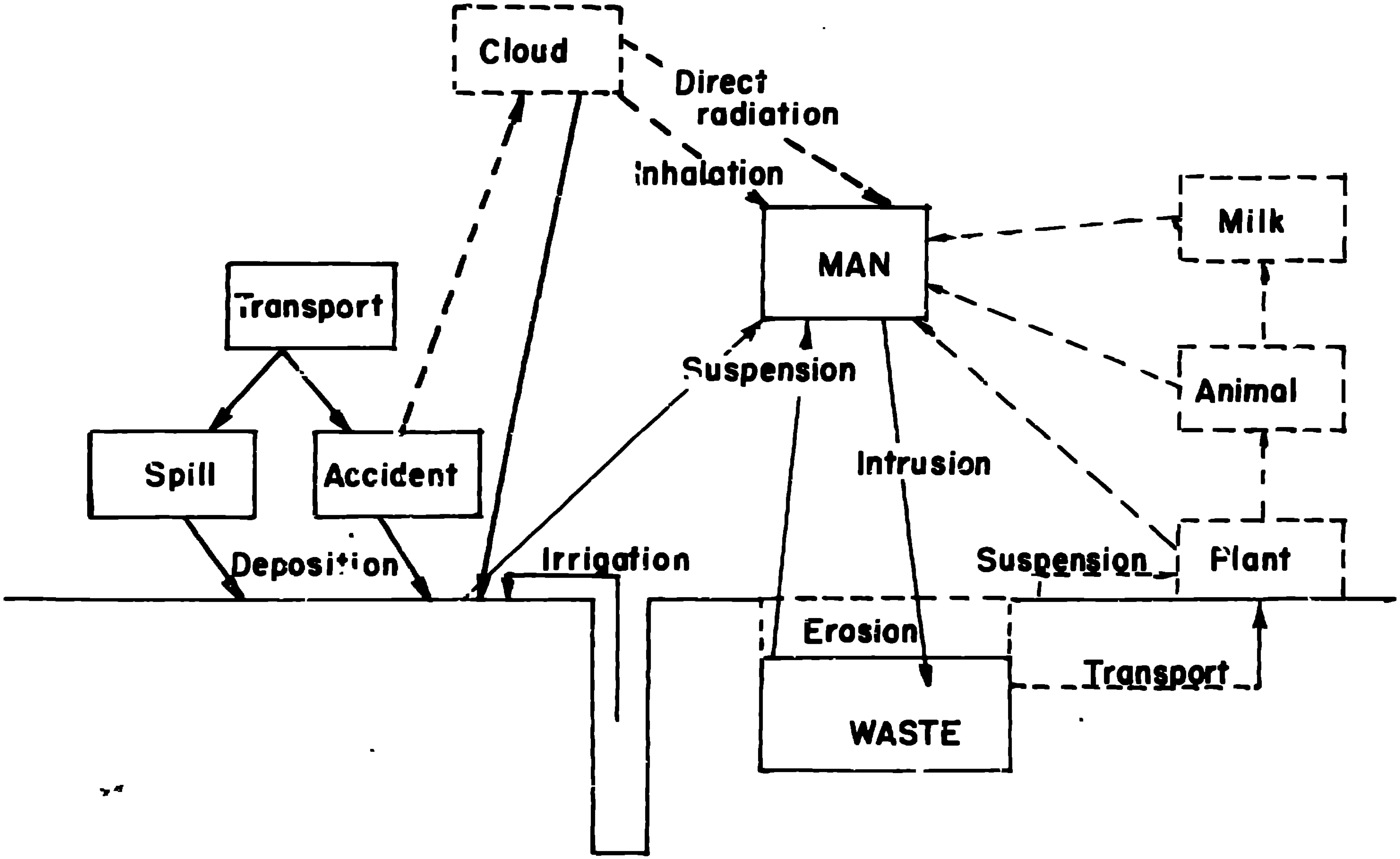
It should also be made clear that the suspensions that we are concerned with are not the true colloidal suspensions that the chemists are used to but, rather, are particles kept in suspension by the turbulent movement of the fluid in which they are carried. Thus, an aerosol resulting from resuspended materials can contain much larger particles than could be indefinitely suspended in still air. In fact, those of you who have been caught in sand storms with strong winds will realize that large particles that can sting when they hit can be carried under conditions of highly turbulent winds.

## RESUSPENSION AND LOW-LEVEL WASTES

Now, how does resuspension fit into the analysis of low-level waste? Obviously, if we do our jobs perfectly it will not become a factor. There are, however, complications such as accidents or spills that must be considered and accounted for as well as a few potential complications that could arise with the long-term behaviour of the burial grounds.

In figure 1, we find an elementary schematic drawing of a few ways that people can be exposed from low level waste operations. A number of the pathways to man have no connection with resuspension but I have included some of these as dotted boxes and lines for the sake of completeness.

The transport accidents and spills can result in contaminated surfaces that can give rise to resuspension and inhalation of


Cloud
Direct
radiation
Inhalation
MAN
Milk
Transport
Suspension
Animal
Spill
Accident
Intrusion
Deposition
Irrigation
Suspension
Plant
Erosion
Transport
WASTE

radioactive materials by man. These, however, should be of relatively minor concern, from the resuspension point of view, because they are usually noted and the area cleaned before serious resuspension can occur. There may be some long-term build-up of activity at places such as loading docks where the material could be resuspended, but this problem can be controlled by monitoring. These potential problems are encountered in the operational phase of the disposal area and can be handled by "institutional" methods because the workers are already there.

However, there are later opportunities for movement of radioactivity to surfaces where resuspension could be a factor. Some of these are shown in Fig. 1. For example, transport of the activity to the surface by water, ants, burrowing mammals or other means can produce a source exposed to winds or other disturbances, that could result in resuspension. The possibility that could expose the largest number of people to small quantities starts with transport to an aquifer. The water from this aquifer could be withdrawn from wells and used for irrigation, with the radioactive materials adsorbing on clays or humus to gradually produce large contaminated areas. If the aquifer empties into a stream, radioactive materials will accumulate in sediments which can be deposited on flood plains or the water can be used for irrigation with the same result as the use of well water. One aspect of resuspension in these cases which leads to the food pathway is the resuspension and deposition on food plants. Experience with nuclides that are only poorly taken up by plants indicates that this can be an important factor.

Another series of pathways involving resuspension occurs in disposal areas containing long-lived radionuclides. Here we can postulate eventual removal of the cover material by erosion, either by wind or water. When this occurs, we are left with a contaminated area to depths of several meters, augmented by surface contamination in the surrounding area caused by the materials removed and carried downwind or downstream. This radioactive material can be resuspended by winds or by movement in the area. This is a futuristic scenario depending upon the particular site of disposal. With average erosion rates, it could occur some thousands or tens of thousands of years from now although gully erosion could occur much faster but on a limited scale. In some areas, the net erosion pattern is such that the disposal area will be simply buried deeper, but the present tendency to look for areas that are "high and dry" to site disposal areas could eliminate this possibility because the high sites with a long distance to the water table are just those that will have a negative-gain erosion potential.

The intrusion case, i.e. where an individual digs into an area, either knowingly or unknowingly, results in resuspension caused by his activities. In an enclosed space this can result in high concentrations of dust and associated radioactive materials with the individual inhaling these materials. However, this exposure will be limited to the individual or individuals concerned unless contaminated items or materials are removed and taken to a place where others can be involved.

This possibility brings up the case in which an archeologist, either amateur or professional, investigates these disposal areas for "treasures" of the past. Old burial grounds are the source of much of our knowledge of the prehistoric past and they serve as magnets to draw those interested in history. We hope that the level of knowledge in the future will be such that proper precautions are taken when this event does occur but this is just the type of point that we cannot assure without surveillance of disposal areas until the radionuclides have decayed. Obviously any contamination on any objects removed could serve as a source of resuspension and inhalation by any individual who handles or works with these objects.

One special case in this category results from the current practice of using non-degradable plastics to contain the contamination during handling of the wastes en route to the disposal area. Current information gives little reason to believe that these plastics will not preserve their contents and remain intact under the conditions of burial in the soil. This raises the possibility of recovery of such packages with consequent exposure when the package is opened.

## CLASSES OF RESUSPENSION

We have divided the overall resuspension problem into three classes defined by both their characteristics and the information needed to solve them.

The first class is wind resuspension. This occurs when the wind blowing over a field resuspends particles and moves them downwind. Much is known about the mechanics of this class through the many studies of wind erosion of agricultural fields. In essence, there is little suspension of soil particles unless a phenomenon called "saltation" occurs. Here, particles on the order of 100-200 µm in diameter start rolling over the surface and then jump into the air under the pressure of the wind. They, then, travel forward with the wind, gaining energy and meanwhile falling under the force of gravity, until they impact on the ground. This impact dislodges other smaller particles that are suspended in the air. Such a process will start at the edge of a field and increase in intensity downwind until a maximum is reached. One other process for wind resuspension, that has not been well investigated could result from the deposition of an aerosol on vegetation. Presumably any of this material that is not bound to the foliage by adsorption or absorption could be dislodged by movement of the foliage under the action of the wind.

The second class of resuspension is that caused by mechanical disturbance of the soil with the resuspended particles moving downwind to expose people. This could be, for example, a farmer plowing a field or people walking or working and disturbing the soil. The familiar dust cloud raised by such activities in dry weather is a sign of such resuspension. Here the forces required for resuspension come from the activity but the movement, once the material is in the air, is dependent upon the winds. Many such disturbances are point sources at the point of disturbance rather than a broad area source as with wind resuspension. Another difference between these two classes is the depth to which the disturbance reaches. In wind resuspension the depth from which resuspension can occur is dependent upon the depth reached by the saltating particle or fairly shallow. In mechanical disturbance the depth can be inches or even feet depending upon the type of disturbance. Thus a source at greater depth can be resuspended than occurs with winds.

The final class is local resuspension. This is the resuspension leading to a cloud in the immediate vicinity of an individual causing the disturbance. It can apply to an individual handling a contaminated object, to an individual digging a hole in contaminated soil or to the dust cloud surrounding a farmer plowing a field. Whereas the concern with the previous two classes was with people downwind from the source of the resuspension, the concern with this class is with the individual causing the disturbance.

## EVALUATION OF RESUSPENSION

Now that we have pointed out some of the ways in which the resuspension pathway to men can be of interest to low-level waste disposal, how can we evaluate its seriousness? In other words, if we can define a source term how can we evaluate the potential exposure to man? The only proper answer at this time is that we do it with considerable uncertainty and with many assumptions. Unfortunately, the studies required to better understand these problems and to obtain adequate coefficients for use are not well funded.

There are three methods, or models, for estimating resuspension: the resuspension factor, the resuspension rate and the mass loading of dust in the air.

The resuspension factor is defined as the ratio of the air concentration resulting from resuspension to the quantity of contaminant per unit area at the location where the air sample was taken. Usually, the air concentration is in activity per $m^3$ and the ground contamination is in activity per $m^2$. Thus, the units of the resuspension factor are $m^{-1}$. There are many values of the resuspension factor in the literature because it has been the most widely used method for many years and measurements are relatively simple. Typical of these values are those in a table by Mishina [3]. In this table, the values vary over about 10 order of magnitude. However, closer examination of this table shows that wind resuspension with freshly deposited material is in the range of $10^{-8}$ to $2\times10^{-6}$ $m^{-1}$ and for aged deposits from $6\times10^{-10}$ to $10^{-13}$ $m^{-1}$.

For mechanical disturbance the range seems to be from $2\times10^{-6}$ to $7\times10^{-5}$ $m^{-1}$. However, many of these tests were done in arid country and may not be typical of other areas.

A decrease in the resuspension with time can be expected following deposition from the atmosphere. This decrease is caused by penetration of the contaminant into the soil or by other means of fixation, such as adsorption on large soil particles. Initially, rather crude measurements at the Nevada Test Site indicated a decrease with a half life of about one month [4]. However, as information has accumulated, it is apparent that any decrease with time is over a much longer period of time than one month. Anspaugh [5] has formulated a relation in which the resuspension is initially $10^{-4}$ $m^{-1}$ with a decrease over a period of several years to $10^{-9}$ $m^{-1}$. It should be stressed, however, that such a relation is based upon meager data obtained in only one area. It may also be noted that such a decrease with time will probably not occur for other types of deposition such as liquid spills or contaminants brought to the surface from a below grade disposal site because these actions result in an initial mixing of the contaminant with the soil.

The resuspension factor has conceptual problems when it is used for describing wind or mechanical resuspension. For example, it does not account for resuspension that occurs upwind. It is primarily an empirical concept with little hope of eventually describing the important variables involved in resuspension. However, from a practical standpoint, most of the past measurements have been made using this method of interpretation so that some data are available. The resuspension factor, or some variation of it, may also be a likely choice in describing local resuspension because the receptor and the source of contamination in the air are at the same place.

The second method of describing resuspension is through the use of the resuspension rate. The resuspension rate is the fraction of the contaminant in the ground that is resuspended per unit time. This rate describes a source term that can be used with the known correlations for meterological dispersion to estimate the air concentrations of the contaminant downwind. There are not many measurements of the resuspension rate available. Sehemel [6] using a nonradioactive contaminant, measured values of $10^{-11}$ to $10^{-7}$ $sec^{-1}$ for wind resuspension in a lightly vegetated area. Anspaugh et al. [7] measured values of $3\times10^{-12}$ to $10^{-9}$ for wind resuspension in an area at the Nevada Test Site. For mechanical resuspension values of $1\times10^{-10}$ to $1\times10^{-15}$ $sec^{-1}$ for an individual walking in a contaminated asphalt highway have been inferred [2] from measurements made by Sehmel [8]. For a truck driving through a tracer on an asphalt highway Sehmel [9] reports values equivalent to rates of $10^{-8}$ to $8\times10^{-3}$ $sec^{-1}$ with the resuspension rate varying with the speed of the vehicle.

The resuspension rate is plagued with the difficulty that too few measurements have been made to allow use for types of soils and in areas different than those in which measurements have been made. It also requires knowledge of the pattern of contamination on or in the soils of the contaminated area. However, it does provide additional detail on the meaning of the measurements and, as information increases, may well be the method of choice for specific areas. It's value in studying the phenomenon of resuspension is illustrated by the findings in the past few years that the rate of resuspension increases with the wind speed at rates up to the 8th power of the wind speed depending upon the type of soil [10].

The third method for calculating resuspension is the mass loading approach. Here, it is assumed that the dust in the air has the same concentration of contaminants as occurs in the soils. Anspaugh et al. [11] have collected information from a number of sources and have shown that reasonable agreement between measured and calculated concentrations can be had if one assumes, for the calculation, that the concentration of dust in the air is 100 ug per $m^3$. Since it is doubtful that the actual concentration is this high, this finding should be regarded as a correlation rather than as a true relation between actual dust and concentration of contaminant.

There are problems with this concept also in that the measured mass loading at a given point depends upon the dust which could have arisen from a large distance upwind and would serve to dilute the dust from the contaminated area, particularly if the contaminated area is small. There have also been questions raised as to the source of the dust from the soil. That is, if the soil contains a large fraction of smaller particles which contain all of the activity, the concentration in this fraction is the one that should be used in the calculations. One investigator [12] has gone so far as to destroy all of the natural aggregates in the soil and to use the concentration in the remaining small particles, which do not exist in nature, as the basis of the calculation. However, all correction factors suggested for this effect using the particle size distribution in natural soil have been comparatively small, less than a factor of two. The use of the mass loading has certain value, however, particularly in view of the correlation mentioned earlier. It should be noted that this correlation was obtained on ambient air with no disturbances in the vicinity. Thus, if it is to be used, the mass loading should be increased by some factor to allow for the possibility of mechanical disturbance. We believe that the mass loading may be the best method for generic studies not tied to a specific site.

## DISCUSSION

This has been a very brief discussion of the role of resuspension in low level waste management. Other references are available that will provide additional detail [1,2]. However, it is apparent that the information available is not really adequate to do more than make a crude estimate of the inhalation problem from any of the three classes of resuspension. Additional studies, providing both basic understandings of the mechanisms of wind resuspension and empirical data tied to specific types of areas and actions are needed to provide data for better estimates.

## REFERENCES

1. G. A. Sehmel, "Transuranic and Tracer Simulant Resuspension," Transuranic Elements in the Environment, W. C. Hanson Ed., Tech. Info. Center, U.S. Dept. of Energy (1980).

2. J. W. Healy, "Review of Resuspension Models," Transuranic Elements in the Environment, W. C. Hanson Ed., Tech. Info. Center, U.S. Dept. of Energy (1980).

3. J. Mishima, "A Review of Research on Plutonium Releases During Overheating and Fires," Hanford Laboratories Report HW-83668 (1964).

4. R. H. Wilson, R. G. Thomas, and J. N. Stannard, "Biomedical and Aerosol Studies Associated with a Field Release of Plutonium," University of Rochester Atomic Energy Project Report WT-1511 (November 1960).

5. L. R. Anspaugh, J. H. Shinn, and D. W. Wilson, "Evaluation of the Resuspension Pathway Toward Protective Guidelines for Soil Contamination with Radioactivity," Population Dose Evaluation and Standards for Man and his Environment, Symposium Proceedings, Portoroz, STI/PUB/375, International Atomic Energy Agency, Vienna (1974).

6. G. A. Sehmel, "Plutonium and Tracer Particle Resuspension: An Overview of Selected Battelle-Northwest Experiments," Transuranics in Natural Environments, Symposium Proceedings, M. G. White and P. B. Dunaway, Eds., ERDA Report NVO-178, pp. 181-210, Nevada Operations Office, NTIS.

7. L. R. Anspaugh, P. L. Phelps, N. C. Kennedy, J. H. Shinn, and J. M. Reichmann, "Experimental Studies on the Resuspension of Plutonium from Aged Sources at the Nevada Test Site, Atmosphere - Surface Exchange of Particulate and Gaseous Pollutants (1974)," ERDA Symposium Series, No. 36, R. J. Englemann and G. A. Sehmel Coordinators, pp. 727-743, CONF-740921, NTIS (1976).

8. G. A. Sehmel, "Tracer Particle Resuspension Caused by Wind Forces Upon an Asphalt Surface," Pacific Northwest Laboratory Annual Report for 1976 to the USAEC Division of Biology and Medicine, Part I, Atmospheric Sciences, Battelle Pacific Northwest Laboratory Report BNWL-1651 (Pt1), pp. 136-138, NTIS (1972).

9. G. A. Sehmel, "Particle Resuspension from an Asphalt Road Caused by Car and Truck Traffic," Atmos. Environ., 7:291-309 (1973).

10. D. A. Gillette, and I. H. Blifford, Jr., "Measurements of Aerosol Size Distribution and Vertical Fluxes of Aerosols on Land Subject to Wind Erosion," J. Appl. Meteorol., 11, 977-987 (1972).

11. L. R. Anspaugh, J. H. Shinn, P. L. Philps, and N. C. Kennedy, "Resuspension and Redistribution of Plutonium in Soils," Health Phys., 29, 571-582 (1975).

12. C. J. Johnson, R. R. Tidball and R. C. Severson, "Plutonium Hazard in Respirable Dust on the Surface of Soil," Science, 193, 488 (1970).

## FIGURE LIST

### Caption

Fig. 1. Schematic drawing of pathways to man from low-level waste operations. Solid lines are related to resuspension while dotted lines are other pathways.